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NOTES

ON THE

PHYSICAL PHENOMENA OF LAKE HARBORS.

BY

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Notes on the Physical Phenomena of Lake Harbors.

Contributed to the Proceedings of the Engineers' Club of Philadelphia by Mr. Geo. Y. Wisner, Member of the American Society of Civil Engineers, formerly Assistant Engineer United States Lake Survey.

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A study of the physical features of sea-coast harbors reveals certain typical forms of channels and bars, which depend for their uniformity upon the action of the tides and currents flowing under similar conditions.* On the lakes where no appreciable tides exist, it has been assumed by many of the engineers who have had charge of the various works of harbor improvements, that the movement of drift and the formation of bars were entirely dependent on wind-wave action, and that the laws governing such formation had no analogy to those existing on a tidal coast. A comparison of the entrances of lake harbors with those on the sea coast shows such striking resemblances in contour lines and shape of bars, that the inference at once arises that the same general laws of nature exist in each case.

On certain portions of the lake coasts the rivers, instead of being normal to the shore, flow for considerable distances parallel to the coast and then empty into the lake through channels of the same general direction; while on other portions of the same lake coast, and under the action of similar prevailing winds, the tendency of the streams is to empty into lakes through channels bending in the opposite direction.

The improvement of mouths of rivers for harbor purposes has usually been accomplished by building parallel piers from deep water in the river to deep water in the lake. The result of these works on the lake action has been to form an accumulation of drift on one side of the piers, and a movement of the crest of the bar into deeper water. On any given coast it may easily be predicted on which side of a pier drift will accumulate.

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* See "Physical Phenomena of Harbor Entrances," by Lewis M. Haupt, C.E., Proceedings, American Philosophical Society, Phila., 1888.

Strong littoral currents also exist along the shores, varying in directions and intensity according to locality and conformation of coast line. Near the head of Lake Michigan, for instance, these currents are southerly along each shore. About midway of the coast, on either side of the lake, they are found flowing sometimes in one direction, and then again in the opposite, while farther down the coast the currents are almost continuously northerly. The flexure of mouths of rivers and shape of bars conform in every instance to that which might be expected under the action of natural forces tending to produce such currents.

Lake harbors, consisting of small bays with outlying islands, and gravel bars have the same general characteristics as those on the Atlantic coast. The spits and bars forming the lake side of the harbors usually have elongated points, curving inwards on one side of the entrance, and a well-rounded point on the opposite side. Gradual erosion goes on continuously along the blunt point, while the sharp point follows, leaving the natural cross-section of the channel in the gorge the same from year to year.

These natural characteristics are well illustrated at the Harbor of Grand Marais, Lake Superior, where the forces of nature, if properly assisted, would make one of the grandest harbors on the whole chain of lakes, but which, under the plans adopted (estimated to cost $500,000), will at best prove but a doubtful experiment. See Plate 1.

Major Robert, in a report to the Chief of Engineers, January, 1881, in speaking of the changes that had occurred at the above harbor since the previous survey made in 1867, says: "The only thing learned by investigating these changes that affect the construction of the piers at the proposed site, is that there is a large amount of shore drift, which will in the future require the *piers to be extended, as has been found necessary at nearly all the harbors on Lake Michigan.*" . . .

"To facilitate entering the channel it is proposed to extend the piers to a depth 4 feet greater than that of the channel. As the shore drift is very large, there will not be 24 feet of water at the end of the piers when they are finished as proposed. If completed in ten years, however, it is believed that there will be over 20 feet of water at the head of the piers where there is now 24 feet."

Mr. L. Y. Shermerhorn, in a report, Jan., 1881, says in regard

to the above harbor: "A comparison of the west spit as it now exists, with its position as determined by the lake survey of 1867 shows that the east end of the spit has advanced into the bay 400 feet, and placing the end of the spit now where in 1867 there was a depth of water of 55 feet. This advance of the west spit since 1867 has been accomplished by the deposition of about 500,000 cubic yards of material, and seems to be a measure of the larger amount of shore drift at this point. . . . The advance of the west spit has been accompanied with the retrocession of the east spit for a distance of 300 feet. Borings indicate that the lake bed north of the west spit is composed of sand, gravel and coarse drift, superimposed on a bed of clay."

The drift formation in front of this harbor indicates that at some early date it was simply an indentation of the coast line, and that the accumulation of drift has closed the opening, until the forces of nature tending to maintain an open channel from the harbor to the lake are in equilibrium with those tending to close it.

As no great amount of water flows into this harbor from its natural drainage area, the question arises, why has not this immense amount of drift, in connection with wave action, closed this entrance years ago.

In 1883 a single storm completely closed a 12-foot channel dredged through the spit between the piers (see Plate 1), and still the natural entrance has retained approximately the same cross-section that it had 60 years ago when Bayfield made his survey. Were no other forces acting at this point than those due to wave action, this entrance would be completely closed in a single season.

As is well known the area of the great lakes lie in a region subject to very sudden and great barometrical disturbances. These barometric inequalities of pressure on the lake surface set in motion series of oscillations varying from 6 inches to 2 feet in amplitude, and with intervals of 20 minutes to $1\frac{1}{2}$ hours between crests depending on locality of disturbing force and the conformation of the coast line.* In extreme cases waves of this character have been observed on Lake Superior, with crests 5 feet above the general level of the lake surface.

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* See "Observations on the Oscillations of Lake Michigan," by Rudolph Hering, printed in Vol. VI, No. 2, Proceeding of Engineers' Club of Phila., March, 1887.

From observations of these oscillations, extending through a period of over twenty years, I have found that the average oscillations in many places is not far from one foot. At Grand Marias Harbor (Plate 1), it is often as much as 18 inches, with intervals of about one hour between crests of waves. The oscillations at the above place approach the shore from the northwest, producing a strong littoral current to the eastward, and a constant *ebb* and *flow* between lake and harbor of sufficient force to maintain a 6-foot channel over the bar against the immense wave action, tending to completely close the channel.

At Chequamegon Point, near Ashland, Wis., the effect of these forces is very clearly illustrated by the changes that have occurred there during the past thirty-five years. This point, in 1852, was a narrow sand spit from 400 feet to 1,000 feet wide, and about seven miles long, extending partially across the mouth of Chequamegon Bay. It is so situated that the oscillations from the lake can only approach the shore obliquely from the northwest. From 1852 to 1869 a continual erosion took place along the entire length of the point. In 1869 the point near the shore end was only about 300 feet wide, and was covered with timber. Some time, about 1872, a breach occurred near the shore end of the point, and soon afterwards widened to nearly a half-mile in width. Since the opening of the breach no erosion has taken place to the northwest, along narrow portion of point. A heavy current flows back and forth through the cut, alternating about once every hour—the flow towards the bay being the stronger, owing to the ebb flow from the bay escaping much more readily through the deep water channel at the end of the point. The action of the current through the breach has deadened the littoral current to the northwest of the cut. The point at the north side of cut is being gradually eroded, and as it recedes it is followed by the sand-point from the main shore. (See Plate 2.)

The cure for this trouble proposed by a recent Engineer Board is to permanently close the breach with a pile dike. This recommendation needs no comment.

The above are fair examples of the physical phenomena to be found at most of the lake harbor entrances. That these oscillations exist, as has been stated, no one familiar with the lakes will deny. That their effect is different from that of tidal action is difficult to conceive.

PLATE 1

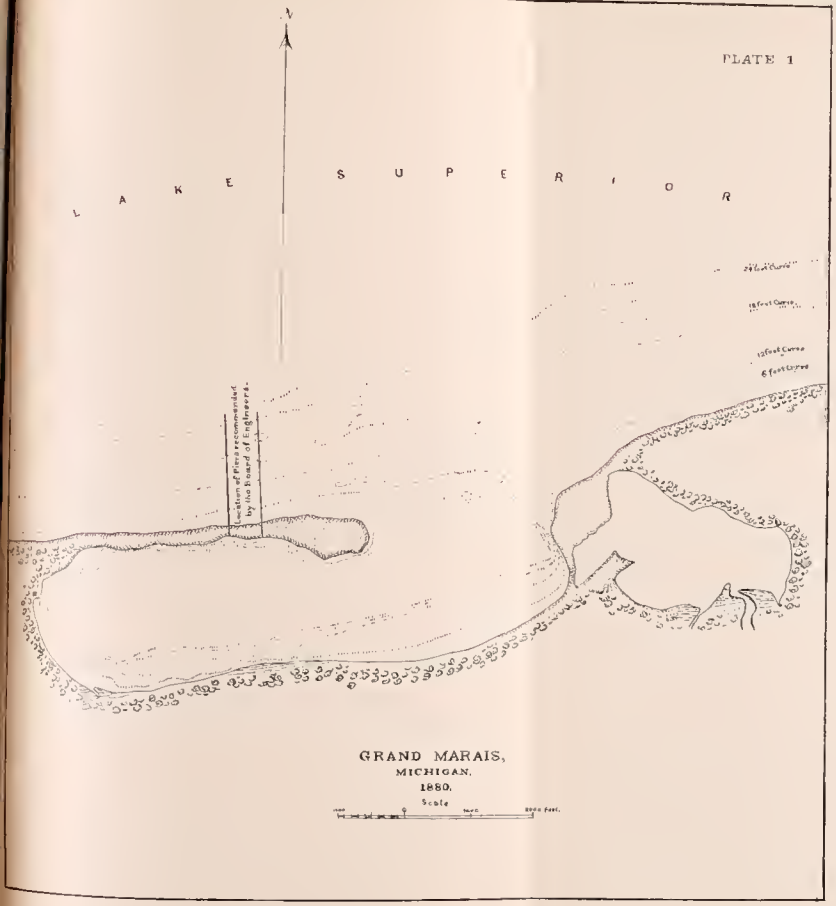

Plate 2.